Langhoff

OCCASIONAL PAPER No. 50 September 18, 1935.

SOUTHERN FOREST EXPERIMENT STATION

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New Orleans, La.

KILLING UNDESIRABLE HARDWOODS IN SOUTHERN FORESTS

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This paper releases data gathered in recent and current investigations of the Southern Forest Experiment Station. The information contained herein is subject to correction or modification following further investigation.

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STAND IMPROVEMENT: THE ELIMINATION OF UNDESIRABLE TREES

The improvement of forest stands in the South, as in other forest regions of the United States, is effected largely and often entirely by the felling or killing of undesirable trees. Trees may be considered undesirable because they are variously:

1. - Unmerchantable, even though of merchantable size.

2. - Potentially unmerchantable even when larger, because of species, form, or quality.

3. - Doubtfully merchantable, or of very low value, either now or in the future, and crowding or overtopping desirable crop trees or potential crop trees.

4. - Defective and providing an abundant source of infection to desirable trees.

5. - Crowding more valuable trees to such an extent that the growth of the more valuable trees is seriously retarded.

Stand improvement is applicable throughout the southern forest region, especially in restocking cut-over areas where the growth of valuable young pines is being suppressed or retarded by unmerchantable or less valuable hardwoods. Thousands of acres in this condition in the National Forests of the South have already been covered systematically by stand-improvement or so-called cultural operations, and other millions of acres are in need of such treatment.

There are three basic methods of eliminating undesirable trees from forest stands: (1) by felling or cutting, (2) by girdling, and (3) by poisoning. These methods will be considered in turn, discussed in some detail, compared and evaluated, and a brief summary will be presented in the form of conclusions. This paper deals only with the killing of undesirable hardwoods. It does not consider *which* or *how many* hardwoods should be eliminated as undesirable, but only the different methods of eliminating undesirable hardwoods, once chosen. Stand improvement--like most other beneficial treatments--can be overdone, and every tree that falls into one of the five categories of the first paragraph should not necessarily be eliminated from a given stand. The list is given only to describe specifically the kind of trees that under various circumstances often need to be removed from further competition in a stand by one of the methods discussed below. Another point to be borne in mind is that the criterion of success in killing undesirable hardwoods in stand-improvement work is largely the death of the crown, or at least the removal of the crown competition, and secondarily the prevention or reduction of undesirable sprouting, of single trees or groups of trees. This paper does not consider the complete elimination of entire stands for the purpose of planting with desirable species, or for agricultural or other nonforest use.

SOURCES OF INFORMATION

In preparing this paper, experimental data collected by the Southern Forest Experiment Station have comprised the principal source of information. The forest types and localities from which these data were collected are as follows: Shortleaf pine-mixed hardwood type on the Ouachita National Forest, near Mount Ida, Ark.; loblolly-shortleaf-mixed hardwood type near Urania, La.; and longleaf pine-scrub oak types on the Choctawhatchee National Forest, near Valparaiso, Fla., and on the Kisatchie National Forest, near Pollock, La.

Two other important sources of information have been: (1) Observations made by the writers in various parts of the deep South, and (2) publications, mimeographed material, and typewritten reports, not necessarily applying directly to the South. Observations of the results of cutting, girdling, or poisoning have been made in the loblolly-shortleaf-hardwoods type on the Homochitto Division of the DeSoto National Forest in southern Mississippi, and on Texas State Forest No. 1, near Kirbyville, Tex.; and in the longleaf-scrub oak type on Texas State Forest No. 1, and on the University Forest, near Vancleave, Miss. A bibliography of the books, articles, bulletins, and reports that have been consulted will be found at the end of this paper.

Since many of the publications present data that conflict more or less with other publications or with our own observations and experiments, it has been necessary to sift and weigh all available information very carefully before drawing conclusions. In arriving at conclusions, our own data and experiences have naturally been relied on most heavily, but not exclusively. The conclusions concerning the poisoning of undesirable trees, as derived from our own observations and experiments, are substantiated in general by unpublished, comprehensive experimental data secured and analyzed by Mr. G. R. Boyd of the Bureau of Agricultural Engineering, U. S. Department of Agriculture.

METHODS OF ELIMINATING UNDESIRABLE TREES

Felling

Felling is, of course, a sure and immediately effective method of eliminating undesirable trees, but for all except the smallest trees it has two serious disadvantages. In the first place, it may be difficult or impossible to fell a large-crowned, branchy, stiff-limbed wolf tree without causing damage to the very trees that it is desired to release. Large oaks (especially post oaks, which usually have wide crowns composed of many long, stiff, almost horizontal limbs) are generally more difficult to fell without causing damage than are red and black gums, which tend to have narrower crowns of less rigid branches. A second disadvantage, and one that is greatly accentuated on large-scale operations, is that felling is the most time-consuming and expensive of the three basic methods. Felling takes from about 1½ to 9 times as long as girdling, depending on the diameter and species of the tree and the type of girdling. Felling a 12-inch oak, for example, takes about 7 to 9 times as long as "single-hack" or "frill" girdling, and about 1½ to 2 times as long as "notch" girdling. These ratios, moreover, do not by any means tell the full story, because at least the larger felled trees must be lopped to reduce fire hazard and maintain the accessibility of the stand. The lopping will often take even longer than the felling.

The disadvantages of felling become more pronounced as the size of the tree increases, and for small trees up to, say, 3 to 5 inches in diameter at breast height are not important. Small trees can usually be felled without causing damage, and the slight disadvantage of somewhat greater cost is offset by the certainty of removing the crown competition and by the reduction of the fire hazard caused by leaving a tree on the ground rather than a standing dead tree. Trees larger than 3 to 5 inches in diameter at breast height should be felled rather than girdled, however, if they are so defective, deeply fire-scarred, or leaning that they are likely to break or blow over soon after girdling.

A possible disadvantage of felling small trees is that they may sprout vigorously. If sprouts will be even less desirable than the existing small trees, it will be best, before taking any action, to consider carefully the respective merits, with regard to sprouting, of felling as compared with girdling, poisoning, and a postponement of any treatment whatever. As a matter of fact, the usually abundant and vigorous sprouting from small hardwoods that have been either felled, girdled, or poisoned indicates that none of these treatments are advisable for releasing small pines or desirable hardwoods (say less than about 5 feet high) from the competition of small undesirable hardwoods. The sprouts resulting from any of these treatments are likely to be much more injurious to the desirable small trees than were the original hardwoods. Of course, one or more follow-up treatments could be made to release again all desirable trees affected by sprouts, but unless such follow-up treatments are

practicable, fully justified ,and actually planned, treatment is better omitted in the first place.

An important exception to this last statement must often be made in the case of small longleaf pine seedlings, less than about 4 or 5 feet high, overtopped by scrub oaks which are less than about 8 inches in diameter at breast height. Here, consideration of the general difficulty of securing adequate longleaf reproduction, and of the usual delay that precedes any appreciable height growth of longleaf seedlings, is likely to result in unusually great efforts to release and preserve the existing seedling stand--even though repeated treatments are necessary. The treatment most likely to be successful under these circumstances involves cutting off the hardwoods as close to the ground as possible, and returning to cut the sprouts close to the ground as often as necessary to prevent injury to the desirable trees. The sprouting from high stumps of small hardwoods is usually more abundant and reaches a greater height than the sprouts from stumps cut very close to the ground. Sprouts usually develop freely along the full length and at the top of high stumps of small hardwoods.

Partial felling, or cutting the tree almost but not entirely through and then bending it over at the cut, away from the tree to be released, is often recommended for the reduction of sprouting from small hardwoods. As actually observed in several stands of scrubby oaks in the South, this method reduces the sprouting very little, although there are situations where the method appears to have advantages. For example, consider a pine 3 feet high and overtopped by a large-crowned scrub oak 3 inches in diameter at breast height and 2 feet away. If the oak is felled, the resultant sprouts will probably engulf the pine in a comparatively short time if no follow-up treatment is made. If the stump is cut high the sprouts will be taller and more numerous. If the oak is girdled, despite its small size, it will probably still sprout so profusely as to endanger the pine. If, however, the oak is cut partially through at about 2 feet and bent over away from the pine, the overhead crown competition will be removed and the sprouting, while not eliminated, may be reduced sufficiently to make further release treatments unnecessary. The crowns of bent-over hardwoods may live and apparently flourish for years in a horizontal position. A disadvantage that may often be serious is that the tops constitute a considerable obstruction to fire control.

Lopping is another method of disposing of the crown competition of very small hardwoods. This consists of lopping the top of the undesirable tree at a point several feet below the level of the top of the desirable tree that is to be liberated. It is claimed that this method will effectively and economically reduce both crown competition and sprouting. It is applicable, however, only to very small trees, the crowns of which extend almost or entirely to the ground, and the work may be entirely wasted if the lopped top quickly grows back to a position that crowds the tree that it was intended to release.

GIRDLING

METHODS

Girdling consists of cutting a complete ring of hacks or chips around a tree. To be effective, the girdle or ring must be absolutely complete or continuous and must extend through the bark and usually at least one-half inch into the sapwood. It may be made at any convenient height, since its object is merely to sever and part the vertical strands of cambium or inner bark which comprise the actively growing portion of a living tree trunk. There are several types or methods of girdling, of which the simplest is to make a ring of single, overlapping, downward-slanting hacks with an ax.

This is known as "single-hacking", "frilling", or "ring-girdling." "Double-hacking", or "chip-girdling", consists of making two rings of downward-slanting ax hacks, the second about 2 to 6 inches above the first and resulting in the removal of chips. "Notching" or "notch-girdling" involves the formation of a V-shaped notch by making both downward- and upward-slanting strokes with an ax. "Peeling" or "banding" consists of removing a band of bark 6 inches to 2 or 3 feet wide and can be easily accomplished only during the relatively short period in the spring when the bark may be readily peeled. These various types of girdling are all made with an ax, but other tools may also be used. A paper and pulp company in Canada has found a chain saw more effective and cheaper than an ax, and recent studies by the Lake States Forest Experiment Station have shown that for small pin cherry (up to 7 inches in diameter) either a draw knife or a chain saw is cheaper than an ax. The tool most commonly used, however, is the double-bitted ax. Its greater general utility doubtless accounts in large part for its use in preference to more specialized tools, but lack of knowledge and experience concerning the other tools is also an important factor.

The more elaborate and hence more costly methods of girdling are more certain to be effective because the completeness of the girdle can be easily and quickly checked, and because the comparatively wide gap made in the cambium makes it impossible for most trees to bridge the girdle with callous growth. The simpler and cheaper methods are difficult to supervise and inspect. Unless the men doing the girdling are unusually efficient or conscientious, or the particular species are very easy to kill, it is quite possible that a large percentage of the girdled trees may not be killed at all. In general, "double-hacking" or "chip-girdling" offers the best combination of cheapness and effectiveness. With any form of girdling, it is especially necessary to girdle carefully around deep fire scars or other cavities. The living tissues at the edges of such cavities are often curved deeply inward and are difficult to cut through completely. If it is impossible to cut these tissues within a cavity, the girdle should be cut either *around* the cavity, outlining it with a complete, continuous series of cuts, or completely *above* the cavity. Hardwoods that are relatively difficult to kill by girdling (especially black gum, red or sweet gum, and elms) should be girdled at least 2 inches into the sapwood.

LABOR COSTS

The labor cost of girdling in stand-improvement work naturally varies greatly with the tool, the method, the species (whether hard- or soft-textured), the number of trees per acre, the topography, and the efficiency of the labor. Thus "average" costs are subject to considerable variation. However, certain basic averages can be given and examples from actual operations have considerable value. For "frilling", it takes about 0.4 minute for a 6-inch tree, 0.6 minute for a 10-inch tree, 0.8 minute for a 14-inch tree, and 1.0 minute for an 18-inch tree. For "double-hacking", these figures are approximately doubled; and for "notching", these figures are increased about 4 or 5 times. Actual stand-improvement operations in the South, under widely varying conditions, generally average between 0.2 and 0.8 acre per man-hour, or 1.25 to 5 man-hours per acre.

RESULTS

Granted that a hardwood is completely girdled, how soon will it die, how and when will it fall, what damage will it do in falling, and how much will it sprout? Answers to these questions were obtained from studies made (1) in cut-over stands of shortleaf pine and mixed hardwoods on the Ouachita National Forest, Ark., between 1929 and 1934, and (2) in cut-over stands of loblolly and shortleaf pines and

mixed hardwoods at Urania, La., between 1933 and 1935 (not yet finished).

In the course of three seasons (October 1929, July 1930, and May 1931) on the Ouachita National Forest, 333 undesirable hardwoods of 10 very common species were girdled by single-hacking or frilling. The 10 species were northern red oak,[1] southern red oak,[2] black oak,[3] and blackjack oak[4] (all in the botanical group of black oaks), white oak[5] and post oak[6] (in the group of white oaks), mockernut hickory,[7] black hickory,[8] black gum,[9] and winged elm,[10] but only the 6 oaks and 2 hickories were adequately represented. The girdled trees ranged from 4 to 23 inches in diameter at breast height. A few trees were incompletely girdled and were still living 5 years after treatment, but the discussion below is concerned only with the trees that were completely girdled. As an indication of the efficiency of the work, carried on with ordinary local labor, only 11 trees, or 3 percent, were later noted as incompletely girdled (although others may actually have been incompletely girdled but died anyway).

In the Urania study, 35 undesirable hardwoods of 8 species were girdled by double-hacking or chip-girdling in February 1933, and 118 undesirable hardwoods of 10 species were girdled with notches in April 1933. The trees ranged from 10 to 31 inches in diameter at breast height, and post oak,[6] red gum,[11] and black gum[9] were the most common species. Only 2 trees, or 1.3 percent, were incompletely girdled. The results given below apply only to the period of 2 years that has elapsed to date; the study will continue until all of the girdled trees have fallen.

Mortality

OUACHITA STUDY.--Omitting for the moment the 5 black gums in the study, all of the 180 trees girdled in October 1929, all of the 97 trees girdled in July 1930, and all of the 40 trees girdled in May 1931 were dead in November 1934, i.e., after periods of 5, 4-1/3, and 3-1/2 years, respectively. Of the 5 black gums girdled in October 1929, 3 were still living in November 1934.

Again omitting the black gums, the following rates of mortality were observed: Nine months after the October 1929 girdling, 69 percent of the trees were dead; 10 months after the July 1930 girdling, 80 percent of the trees were dead; and 19 months after the October 1929 girdling, 89 percent of the trees were dead.

The group of black oaks, exclusive of blackjack oak, succumbed the most quickly; all were dead 9 months after the October 1929 girdling and 10 months after the July 1930 girdling. Blackjack oak was also killed rather quickly; 66 percent were dead in 9 months, and 93 percent in 19 months, after the October 1929 girdling. The white and post oaks and the hickories reacted similarly to the October 1929 girdling; only 38 and 37 percents were dead in 9 months, and 76 and 80 percents were dead in 19 months, respectively. Ten months after the July 1930 girdling, however, 86 percent of the white and post oaks, but only 35 percent of the hickories, were dead.

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[1] *Quercus borealis maxima* (Marsh.) Ashe
[2] *Quercus rubra* L.
[3] *Quercus velutina* La Marck
[4] *Quercus marilandica* Muench.
[5] *Quercus alba* L.
[6] *Quercus stellata* Wang.
[7] *Hicoria alba* (L.) Britt.
[8] *Hicoria buckleyi arkansana* (Sarg.) Ashe
[9] *Nyssa sylvatica* Marsh.
[10] *Ulmus alata* Michx.
[11] *Liquidambar styraciflua* L.

URANIA STUDY.--Omitting 11 trees, or 7 percent, that fell while being girdled (due to being hollow, very rotten, or deeply scarred), and also omitting the 2 incompletely girdled trees, 87 percent of the 32 hardwoods girdled in February 1933 and 97 percent of the 108 hardwoods girdled in April 1933 were dead in June 1935. For the February (double-hacked) group, the mortality by species was: Oaks, 100 percent; red gum, 70 percent; and black gum, 67 percent. For the April (notched) group, the corresponding mortality was: Oaks, 100 percent; red gum, 92 percent; and black gum, 95 percent. Thus only the gums were still living in June 1935, but considering the length of the period and the high percentages the results even for these species are eminently satisfactory. Six months after the April notch-girdling, 57 percent of all the trees were dead, and at 13 months, 71 percent were dead. Fifteen months after the February double-hack girdling, however, only 16 percent of all the trees were dead. If the month of treatment has had no significant effect, these figures show that the double-hacked girdles result in a slower rate of mortality than for the notched girdles. The total mortality at about 2 years, however, is not appreciably less for the double hacks than for the notches. The eventual mortality will presumably be 100 percent for both methods. The living gums had unhealthy foliage in 1935 and will probably die within the next year or two.

The group of black or red oaks (excluding willow oak) succumbed the most quickly; willow oak, post oak, and white oak ranked next; and red gum and black gum were the slowest to die. Of the April (notch) girdling, all of the black oak group, only 8 percent of the red gums, and none of the black gums, were dead 1 month after treatment. Even 13 months after treatment only 54 percent of the red gums and 26 percent of the black gums were dead. Of the February (double-hack) girdling, 75 percent of the group of black oaks, but none of the red or black gums, were dead 15 months after treatment.

Rate of fall

OUACHITA STUDY.--Standing dead trees constitute a high fire hazard, hence the interest in knowing the rate of fall of girdled trees. Data on this phase of girdling are presented in table 1, which shows for various periods, diameter classes, and species in the Ouachita study the percentages of dead girdled trees that were in the zero- to 8-foot height class. This height class includes trees that had been uprooted, broken at the ground level or girdle, or consisted of a stub or snag less than 8 feet high, and thus represents trees that are actually or essentially "down." The group of black oaks and the hickories showed very similar rates of fall and were, therefore, grouped together. The table shows that the girdled black oaks and hickories fall at a considerably faster rate than do the white oaks. The rate of fall increases more or less with decrease in diameter and with increase in the period since girdling, but the relationships are by no means as clear-cut as might be expected.

Inasmuch as table 1 shows that for certain species and sizes only a relatively small percentage of the girdled trees were in the zero- to 8-foot height class 5 years after girdling, the condition of snags over 8 feet high is of interest. If they retain their larger limbs until the entire snag falls, both the fire hazard and the danger of damage to small pine seedlings and saplings are increased. Observations and actual counts of the number of remaining limbs over 5 inches in diameter, however, showed that the girdled trees generally dropped their larger limbs piecemeal and that most of the taller snags still standing 5 years after girdling were almost or entirely devoid of large limbs.

TABLE 1. -- *Percentage of girdled trees in the zero- to 8-foot height class in November 1934, by periods, diameter classes, and species groups. Ouachita National Forest, Ark.*

Tree diameter at breast height	Black oaks[1] and hickories[2]		White oaks[3]		Total	
	Trees girdled	Number in zero- to 8-foot height class in 1934	Trees girdled	Number in zero- to 8-foot height class in 1934	Trees girdled	Number in zero- to 8-foot height class in 1934
Inches	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
5 years after girdling in October 1929:						
4 - 7	75	76	21	52	96	70
8 - 11	35	40	6	33	41	39
12 - 23	26	31	15	20	41	27
4-1/3 years after girdling in July 1930:						
4 - 7	22	55	25	24	47	38
8 - 11	17	53	32	22	49	33
3-1/2 years after girdling in May 1931:						
4 - 7	11	64	10	0	21	33
8 - 11	10	60	9	0	19	32
Total, all three periods:						
4 - 7	108	70	56	30	164	57
8 - 11	62	47	47	19	109	35
12 - 23	26	31	15	20	41	27

[1] Includes black, northern red, southern red, and blackjack oaks.
[2] Includes mockernut and black hickories.
[3] Includes white and post oaks.

URANIA STUDY.--Twelve percent of all the hardwoods notched in April 1933 fell within the first 6 months, 19 percent were down after 13 months, and 35 percent were down after 26 months. These percentages are higher than should be considered typical for the method, since many of the notches were cut unnecessarily wide and deep by inexperienced men. There was a large variation according to species. At 6 months, 25 percent of the red gums, 9 percent of the oaks, and none of the black gums had fallen. At 26 months, 67 percent of the red gums, 21 percent of the oaks, and 18 percent of the black gums had fallen.

Of the hardwoods double-hacked in February 1933, none had fallen 28 months after treatment. This is a strikingly different result from that secured by notching, even allowing for the fact that the latter percentages are higher than would normally be expected.

Damage

OUACHITA STUDY.--One of the reasons for girdling rather than felling is to protect a desirable young stand in an understory from injury by falling trunks and crowns. It is possible, however, that girdled trees may cause as much or even more injury of this nature by their haphazard blowing over or breaking. The sprouts from girdled trees may, also, conceivably cause more injury to desirable reproduction than the ungirdled trees. Thus the actual damage done by girdled trees is of considerable interest.

In the Ouachita study, only 10 percent of the girdled trees injured pine seedlings or saplings by reason of part or all of the deadened tree falling on or against the small pines. An additional 6 percent of the girdled trees produced sprouts that severely suppressed small pine seedlings. Considering the large number of small pines on the experimental area, the number actually damaged by falling trees or limbs, or by sprouts, was very small indeed.

It was not possible to compute the percentage of the total number of small pines damaged, but suffice it to say that the percentage was evidently very small. In fact, at the time of the last examination, 5 years after girdling, it was frequently noted that falling limbs and trees had just barely missed hitting vigorous young shortleaf pines. These small pines are very resilient and flexible, and the falling limbs and trees were for the most part very unsound. These two factors undoubtedly helped to protect many young pines from injury when struck glancing blows by such falling limbs or trees. The damage from this source probably cannot be eliminated, yet it is satisfactorily small and by no means a serious disadvantage of girdling.

The damage caused by sprouts, however, can be largely eliminated by not girdling trees of species and sizes that are likely to sprout prolifically, and which stand directly over pines small enough to be suppressed easily by sprouts. It is usually advisable, for example, not to girdle small hardwoods standing directly over pine seedlings less than about 5 feet high. Small pine seedlings in this position will undoubtedly be retarded in growth, and some or many may die before reaching a height great enough to warrant the girdling of the trees above them. The vigorous sprout growth that may result from girdling small hardwoods, however, is much more likely not only to kill small pines but also to make further pine reproduction more difficult or impossible. Small hardwoods also serve to a greater or less extent as "nurse trees" for small pine seedlings and as "trainers" to keep the pines straight and well pruned; their undesirable competition with these pines is more or less counterbalanced by the desirable protective cover and influence on quality that they provide.

URANIA STUDY.--Twenty-three percent of the trees that have fallen to date have caused some damage to small pines. Although this may seem a rather high figure, the actual damage has been very slight and damage to individual small pines is frequently either of no practical consequence or actually a benefit to the stand as a whole. Probably not over 10 percent of the falling trees have really damaged anything of value in the stand, and this is far outweighed by the general release and liberation of previously suppressed pines. For the most part, the girdled trees are falling apart piecemeal in a very satisfactory manner and, to date, falling limbs have apparently caused no damage whatever.

Sprouting

OUACHITA STUDY.--The sprouting of dead-crowned girdled trees is related to the size of the tree, the species, the season of treatment, and the period since

treatment--to mention only four of the more important factors. The influence of each of these factors may be observed in table 2, where it is evident (1) that sprouting decreases steadily with increase in diameter at breast height and is negligible beyond about 11 inches, (2) that the group of black oaks sprouts more than either the group of white oaks or the hickories, which behave alike, and (3) that the trees girdled in October sprouted most, and in May sprouted least, with July intermediate. Table 2 also appears to indicate that sprouting increases with increase in the period since treatment, but more detailed analyses using the data from intermediate examinations show that the period since treatment actually had very little effect on the percentage of trees sprouting.

TABLE 2. -- *Percentage of dead girdled trees with living sprouts in November 1934, by periods, diameter classes, and species groups. Ouachita National Forest, Ark.*

Tree diameter at breast height	Black oaks [1]		White oaks [2]		Hickories [3]		Total	
	Trees girdled	Number with sprouts	Trees girdled	Number with sprouts	Trees girdled	Number with sprouts	Trees girdled	Number with sprouts
Inches	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
5 years after girdling in October 1929:								
4 - 7	53	81	21	81	22	64	96	77
8 - 11	27	56	6	17	8	25	41	44
12 - 15	12	0	6	0	-	-	18	0
16 - 23	14	21	9	0	-	-	23	13
4-1/3 years after girdling in July 1930:								
4 - 7	5	60	25	44	17	53	47	49
8 - 11	14	36	32	16	3	0	49	20
3-1/2 years after girdling in May 1931:								
4 - 7	5	20	10	20	6	0	21	14
8 - 11	7	14	9	0	3	0	19	5
Total, all three periods:								
4 - 7	63	75	56	54	45	51	164	61
8 - 11	48	44	47	13	14	14	109	27
12 - 15	12	0	6	0	-	-	18	0
16 - 23	14	21	9	0	-	-	23	13

[1] Includes black, northern red, southern red, and blackjack oaks.
[2] Includes white and post oaks.
[3] Includes mockernut and black hickories.

The average number and size of sprouts from sprouting girdled trees in the Ouachita study did not vary appreciably or consistently with species or season of treatment. The relationship to the size of the tree is shown in table 3 for all species girdled in October 1929 and examined in November 1934.

TABLE 3. -- *Data on living sprouts in November 1934 from trees girdled in October 1929. Ouachita National Forest, Ark.*

Tree diameter at breast height	Basis: Number of trees sprouting	Average number of sprouts per tree	Average height of tallest sprout per tree	Average greatest width of entire sprout clump per tree
Inches			*Feet*	
4 - 7	75	4.9	8.0	6.4
8 - 11	18	4.0	7.1	6.3
12 - 15	0	-	-	-
16 - 19	3	2.0	6.0	4.3

URANIA STUDY.--The girdled hardwoods in the Urania study were all 10 inches or more in diameter at breast height and their sprouting in the first 2 years since treatment has been negligible. Indeed, the sprouts have been so few, so small, and so utterly without significance with respect to the liberated small pines (most of which are well over 1 inch in diameter at breast height), that no counts or measurements have been made or are contemplated.

POISONING

METHODS OF APPLICATION

Poisoning consists of the application or injection of a chemical destructive to plant life. There are several methods of application or injection into trees, of which the more common are (1) to swab or pour the poison into a complete girdle or "frill" around the tree, (2) to swab or pour the poison into one or more unconnected hacks, (3) to swab the poison on a completely peeled section of the bole, (4) to pour the poison into auger holes bored into the bole, and (5) to spray the poison on the foliage. A number of different investigators in the United States and in India have shown that the first method is by far the most effective, and usually the only thoroughly effective method of application. The poisoning of one or more unconnected hacks was found to be ineffective in the poisoning experiments made on the Ouachita National Forest, Ark., between 1929 and 1934, the results of which will be given in some detail below. The lateral spread of a poison from the point of application or injection is negligible. Application of poisons to single ax-hacks in the Ouachita study, for example, killed vertical strips of tissue extending some distance above and below the hacks, but essentially no wider than the hacks. The crown as a whole continued to live in a large proportion of the trees so treated.

As a modification of the first method given above, poisoning tools have been devised by Cope and Spaeth and by MacKinney (see references under "III. Poisoning" in the appended bibliography) to reduce the cost of poisoning trees by making it a 1-man rather than a 2-man opration. In both tools the poisonous solution is stored in the long, tubular handle of an implement with a chisel-like cutting edge, and the solution is injected immediately into each incision made by jabbing the blade through the bark and about one-half inch into the sapwood.

POISONS

A large number of different chemicals have been tested for their tree-killing qualities. In the 1929-34 Ouachita study, 15 different chemicals or mixtures of chemicals were tested. In general, arsenicals have been most widely used. Commercial white arsenic in particular has been widely used and has usually been found to be very effective, either in a water solution or mixed with lye in a water solution. Different proportions of white arsenic, lye, and water have been used successfully by several different investigators, so that the arsenic is evidently toxic to trees over a fairly wide range of dilution. Expressed in pounds of white arsenic, pounds of lye, and gallons of water, respectively, effective formulae include the following: 1-1/2-4, 1-1-4, 1-1-2, 1-2-2, 1-0-1, 2-1/2-1 and 4-1-3/8. Regardless of the formula employed, the solution must be prepared and handled very carefully because white arsenic is *very poisonous* and gives off poisonous fumes when in a boiling solution. Indeed, no poisons, and espesially none with an arsenic or chlorate base, should be used without first obtaining specific directions for their proper preparation and handling, and, second, observing specific precautions in their application. Arsenic and many other chemicals are poisonous to cattle and other livestock, so that their use should be limited to stands either not frequented by stock or closed to stock for at least 3 weeks. Among other substances that have been found to be effective in killing trees and shrubs, the following may be mentioned as representative: Sodium and calcium chlorate; potassium chromate and bichromate; copper and iron sulphate; copper, sodium, barium, and zinc chloride; ammonium thiocyanate; formaldehyde; carbolic acid; sodium fluoride; ethylene oxide; cresylic acid; kerosene; and creosote. Different investigators using the same poison have frequently obtained different results, and the results of any one investigator with any one poison frequently show a variability that makes it difficult or impossible to draw specific conclusions. Consequently there is no single "best" poison for killing trees.

COSTS

Since a tree must be completely girdled before the application of a poison will prove thoroughly effective, the cost of poisoning is equal to the cost of girdling ("frilling" will do), plus the cost of preparing and applying the poison. The total cost of poisoning is therefore even more difficult to pin down to reliable "average" values than is the cost of girdling alone, but in general the total cost of poisoning in complete girdles has been found to be from 1.2 to 3 times more expensive than simple girdling. The use of special poisoning tools, such as those described above, may materially reduce the cost of poisoning--especially in brushy stands where "frilling" with an ax is relatively difficult.

RESULTS

With poisoning, as with simple girdling, the principal questions to be answered are: How soon will the trees die, how and when will they fall, what damage will they do in falling, and how much will they sprout? Answers were obtained from the 1929-34 Ouachita study, mentioned above. In the course of three seasons (October 1929, July 1930, and May 1931), 1,355 hardwoods of the same 10 species that were simply girdled (see above under *Girdling: Results*) were completely girdled by "frilling" and one or another of 15 poisonous solutions was poured into the girdles. Most of the conclusions will be drawn from the two largest-scale treatments: a white arsenic and lye treatment applied to 222 trees, and a commercial weed-killer (largely calcium chlorate) applied to 219 trees.

Mortality

Omitting 12 living trees that had been incompletely girdled through carelessness, only 1 of 1,343 trees poisoned in October 1929, July 1930, and May 1931 was still living in November 1934. Sixteen black gums are included in the number treated.

The rate of mortality of completely girdled, poisoned trees varied with the poison and with the species. Combining all species, the following rates were observed: Nine months after the October 1929 poisoning, 97 percent of the 222 arsenite-poisoned trees, 61 percent of the 219 chlorate-poisoned trees, and 79 percent of the 151 miscellaneous-poisoned trees were dead. Nineteen months after the October 1929 poisoning, 97 percent of the arsenite-poisoned trees, 86 percent of the chlorate-poisoned trees, and 98 percent of the miscellaneous-poisoned trees were dead. Of the 8 miscellaneous poisons in these tests, copper sulphate, ferric sulphate, and a sodium arsenite-sodium chloride-potassium nitrate mixture killed the trees most rapidly, and creosote and crude carbolic acid killed the trees most gradually. Ten months after the July 1930 poisoning, 99 percent of 100 arsenite-poisoned trees, 82 percent of each of 100 sodium chlorate-poisoned and 99 zinc meta-arsenite-poisoned trees, and 76 percent of 98 copper sulphate-poisoned trees were dead. Except for the sodium arsenite, copper sulphate, and ferric sulphate treatments, the poisoned trees did not die appreciably, if at all, more quickly than the merely girdled trees.

The group of black oaks, exclusive of blackjack oak, succumbed most quickly to poisoning: 98 percent were dead 9 months after the October 1929 treatment, and 99 percent were dead 10 months after the July 1930 treatment. Blackjack oak was also killed rather quickly by poisoning: 86 percent were dead in 9 months, and 96 percent in 19 months after the October 1929 treatment. The white and post oaks ranked next: 77 percent were dead in 9 months, and 97 percent in 19 months after the October 1929 treatment; and 87 percent were dead 10 months after the July 1930 treatment. Of the hickories, 56 percent were dead in 9 months, and 82 percent in 19 months after the October 1929 treatment; and 64 percent were dead 10 months after the July 1930 treatment. The black gums were the slowest to succumb to poisoning; only 19 percent were dead in 9 months and 50 percent in 19 months after the October 1929 treatment. Although some poisons killed all species sooner than simple girdling, the relative resistance of the different species to poisoning was practically the same as their relative resistance to simple girdling.

Rate of fall

Data on this phase of poisoning are presented in table 4, which shows for various poisons, periods, diameter classes, and species in the Ouachita study the percentages of dead poisoned trees that were in the zero- to 8-foot height class, i.e., that were actually or essentially "down." The group of black oaks and the hickories were grouped together because of their similar rates of fall, and the relationship between this group and the white and post oaks is essentially the same as shown in table 1 for merely girdled trees. Black oaks and hickories fall at a considerably faster rate than do white oaks, and the rate of fall of either group generally increases with decrease in diameter and with increase in the period since poisoning. There is a considerable difference between the rates of fall for the two poisons tested on the largest scale, sodium arsenite and calcium chlorate. The arsenite-poisoned trees fell at a slower rate than did the chlorate-poisoned trees, and in general the former group fell at the same or a slower rate, and the latter group at a faster rate, than did the merely girdled trees. Taking the averages for all treatments shown in table 4, poisoned trees evidently fall at about the same rate as merely girdled trees (table 1),

TABLE 4. -- *Percentage of poisoned trees in the zero- to 8-foot height class in November 1934, by poisons, periods, diameter classes, and species groups. Ouachita National Forest, Ark.*

Poison applied to complete girdles	Tree diameter at breast height	Black oaks[1] and hickories[2]		White oaks[3]		Total	
		Trees girdled	Number in zero- to 8-ft. hgt. class in 1934	Trees girdled	Number in zero- to 8-ft. hgt. class in 1934	Trees girdled	Number in zero- to 8-ft. hgt. class in 1934
	Inches	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
5 years after poisoning in October 1929:							
Sodium arsenite[4]	4 - 7	95	61	38	32	133	53
	8 - 11	34	53	13	0	47	38
	12 - 23	20	40	13	15	33	30
Calcium chlorate[5]	4 - 7	92	84	25	72	117	81
	8 - 11	35	63	8	75	43	65
	12 - 23	29	38	8	37	37	38
4-1/3 years after poisoning in July 1930:							
Sodium arsenite	4 - 7	22	59	27	18	49	37
	8 - 11	18	33	33	9	51	18
Sodium chlorate (33% solution)	4 - 7	21	71	27	37	48	52
	8 - 11	18	50	33	24	51	33
Copper sulphate	4 - 7	24	54	22	23	46	39
	8 - 11	17	24	33	12	50	16
Zinc meta-arsenite	4 - 7	23	48	25	16	48	31
	8 - 11	16	44	34	6	50	18
3-1/2 years after poisoning in May 1931:							
Sodium arsenite	4 - 7	11	73	10	10	21	43
	8 - 11	11	36	7	14	18	28
Sodium chlorate (33% solution)	4 - 7	11	73	10	70	21	71
	8 - 11	10	30	9	11	19	21
Copper sulphate	4 - 7	13	69	11	36	24	54
	8 - 11	8	75	7	14	15	47
Zinc meta-arsenite	4 - 7	10	70	10	20	20	45
	8 - 11	11	27	9	11	20	20
Kerosene	4 - 7	11	64	8	25	19	47
	8 - 11	11	45	10	10	21	29
Total	4 - 7	333	68	213	33	546	54
	8 - 11	189	46	196	14	385	30
	12 - 23	49	39	21	24	70	34

[1] Includes black, northern red, southern red, and blackjack oaks.
[2] Includes mockernut and black hickories.
[3] Includes white and post oaks.
[4] One lb. commercial white arsenic to 1 lb. sodium hydroxide to 4 gals. water.
[5] Two lbs. commercial weed-killer to 1 gal. water.

TABLE 5. -- *Percentage of dead poisoned trees with living sprouts in November 1934, by poisons, periods, diameter classes, and species groups. Ouachita National Forest, Ark.*

Poison applied to complete girdles	Tree diameter at breast height	Black oaks[1]		White oaks[2]		Hickories[3]		Total	
		Trees poi-soned	Number with sprouts	Trees poi-soned	Number with sprouts	Trees poi-soned	Number with sprouts	Trees poi-soned	Number with sprouts
	Inches	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
5 years after poisoning in October 1929:									
Sodium arsenite[4]	4 - 7	66	86	38	63	29	83	133	79
	8 - 11	31	35	13	31	3	0	47	32
	12 - 15	14	7	9	11	1	0	24	8
	16 - 23	5	20	4	0	-	-	9	11
Calcium chlorate[5]	4 - 7	42	71	25	44	51	53	118	58
	8 - 11	29	34	8	12	6	50	43	33
	12 - 15	21	19	4	0	-	-	25	16
	16 - 23	8	0	4	0	-	-	12	0
4-1/3 years after poisoning in July 1930:									
Sodium arsenite	4 - 7	4	100	27	48	18	61	49	57
	8 - 11	14	36	33	6	4	25	51	16
Sodium chlorate (33% solution)	4 - 7	4	25	27	18	17	35	48	25
	8 - 11	14	14	33	21	4	25	51	20
Copper sulphate	4 - 7	6	50	22	36	18	61	46	48
	8 - 11	14	22	33	15	2	50	49	18
Zinc meta-arsenite	4 - 7	5	60	25	36	18	44	48	42
	8 - 11	13	38	34	18	3	33	50	24
3-1/2 years after poisoning in May 1931:									
Sodium arsenite	4 - 7	5	40	10	0	6	33	21	19
	8 - 11	8	0	7	14	3	0	18	6
Sodium chlorate (33% solution)	4 - 7	5	20	10	30	6	17	21	24
	8 - 11	7	14	9	0	3	0	19	5
Copper sulphate	4 - 7	6	17	11	9	7	0	24	8
	8 - 11	6	0	7	0	2	50	15	7
Zinc meta-arsenite	4 - 7	4	0	10	20	6	0	20	10
	8 - 11	8	25	9	0	3	33	20	15
Kerosene	4 - 7	5	60	8	25	6	33	19	37
	8 - 11	8	38	10	20	3	33	21	28
Total	4 - 7	152	69	213	37	182	51	547	50
	8 - 11	152	28	196	14	36	28	384	21
	12 - 15	35	14	13	8	1	0	49	12
	16 - 23	13	8	8	0	-	-	21	5

[1] Includes black, northern red, southern red, and blackjack oaks.
[2] Includes white and post oaks.
[3] Includes mockernut and black hickories.
[4] One lb. commercial white arsenic to 1 lb. sodium hydroxide to 4 gals. water.
[5] Two lbs. commercial weed-killer to 1 gal. water.

due largely to the compensating rates of arsenite- and chlorate-poisoned trees. As with the merely girdled trees, poisoned trees usually fall apart gradually and lose most or all of their large limbs before the main trunk falls.

Damage

The damage done to desirable young pines by poisoned trees falling on or against them, or by the sprouts from poisoned trees, is essentially the same as that caused by the falling or sprouting of merely girdled trees. That is to say, that a very small percentage of poisoned trees cause such damage, and that a negligible percentage of desirable seedlings and saplings are damaged. This statement is based on observations made in the Ouachita study. Since poisoned trees appear to disintegrate and fall in essentially the same manner and at the same rate as merely girdled trees, the discussion of damage caused by girdled trees applies also to poisoned trees.

Sprouting

The sprouting of dead-crowned girdled-and-poisoned trees is affected by the same factors listed for merely girdled trees. Table 5 presents representative data on the sprouting of poisoned trees in a form comparable to table 2 for merely girdled trees, and the conclusions drawn from the data are the same as for girdled trees. In comparing tables 2 and 5, it will be noted that there are no very large or consistent differences beween the percentages of sprouting trees resulting from simple girdling and from poisoning, respectively. The poisons, as a group, may show a slight net advantage, but any such advantage is too uncertain in fact and too small in amount to have any practical significance. For the same species, sizes, seasons, and periods, some poisons were slightly more effective in reducing sprouting, others slightly less effective, than simple girdling. On the basis of the Ouachita study, therefore, we must conclude that poisoning neither reduces nor increases sprouting to any appreciable extent.

The average number and size of sprouts from sprouting poisoned trees in the Ouachita study were essentially the same as those from sprouting trees that had only been girdled. A brief and representative summary, for all species poisoned on a large scale in October 1929 and examined in November 1934, is presented in table 6.

TABLE 6. -- *Data on living sprouts in November 1934 from trees poisoned in October 1929. Ouachita National Forest, Ark.*

Tree diameter at breast height	Basis: Number of trees sprouting		Average number of sprouts per tree		Average height of tallest sprout per tree		Average width of entire sprout clump per tree	
	Treated with sodium arsenite	Treated with calcium chlorate	Treated with sodium arsenite	Treated with calcium chlorate	Treated with sodium arsenite	Treated with calcium chlorate	Treated with sodium arsenite	Treated with calcium chlorate
Inches					*Feet*			
4 - 7	106	71	4.7	3.7	7.4	7.1	5.4	5.1
8 - 11	16	17	2.6	2.6	6.6	7.2	5.1	5.0
12 - 15	2	4	2.5	3.7	5.0	6.7	3.5	2.7

In comparing table 6 with table 3, it will be noted that the poisoned sprouting trees have somewhat fewer and somewhat smaller sprouts than have the merely girdled trees. The differences, however, are very small and are thought to be of no practical significance in ordinary stand-improvement work.

Poisoning versus Girdling

A comparison of the respective merits of poisoning and girdling is readily made by listing the various possible reasons for poisoning rather than merely girdling, and by considering the merits of each separately. The reasons and their merits are as follows:

1. - To kill trees quickly rather than over a period of several months or years. This reason should be sufficient to justify poisoning if the trees to be killed are rapidly spreading a virulent disease, or will--within a year or two--shade out or irreparably deform or stunt desirable trees beneath them. Neither of these conditions is ordinarily a factor in stand-improvement work in southern forests. Provided that the undesirable trees die within, say, 3 or 4 years at the most (and large percentages of girdled trees die in 1 or 2 years), it usually makes little practical difference just when they die. Indeed, a delayed mortality is often considered to be preferable since the stand is then opened up more gradually and the released desirable trees can gradually adjust themselves to the new conditions.

2. - To prevent or greatly reduce sprouting. This reason would justify poisoning (1) if poisoning would actually prevent or greatly reduce sprouting, (2) if the trees to be killed were of a size and species that usually sprout vigorously and prolifically after girdling, and (3) if such sprouting would suppress or seriously interfere with desirable reproduction either already present or expected. With reference to the first qualification, there is some evidence that certain poisons applied at certain seasons will greatly reduce sprouting, but poisons as a group do not appear to reduce sprouting below that resulting from simple girdling. The second qualification or condition often obtains in southern forests, but the third is not usually an important factor. If sprouts will do more damage than the original trees, it is likely that stand improvement should be postponed several years until the reproduction is beyond the reach of ordinary sprouting, and that stand improvement is not an immediate necessity. Ordinarily, some damage from sprouts can be expected and can be tolerated without constituting a serious drawback to the stand-improvement operation as a whole.

3. - To kill trees more cheaply. Since numerous experiments have indicated that poisons are not thoroughly effective unless applied to a continuous girdle, and since (so far as known) a continuous "chip" or "notch" girdle alone will sooner or later kill all individuals of all southern hardwood species, effective poisoning is necessarily more expensive, not cheaper, than simple girdling. Poisoning would be cheaper only if the application of poisons to a few bored augerholes, one or several isolated hacks, or the like, were effective. No such methods are known to be satisfactorily or consistently effective.

4. - To kill trees that survive girdling. Certain southern hardwoods, notably red or sweet gum and black gum, are relatively difficult to kill (at least within 2 or 3 years) by simple girdling. How or why these species some-

times survive apparently complete girdling for at least 5 years is not definitely known, nor is it certain how long a completely girdled, previously sound tree of these species can live. This would be a good reason for poisoning such species but for the facts (1) that red and black gums usually comprise only a part (and frequently only a very small part) of the stand that is to be killed, (2) that many trees (and occasionally a very high percentage) of these species do succumb relatively quickly to simple girdling, (3) that many individuals that do not die directly as a result of simple girdling are soon blown over, breaking at the girdle due to the weakening caused by rot and the removal of mechanical support, and (4) that girdled trees, even though living, provide much less competition to neighboring trees than do ungirdled trees. In other words, the fact that simple girdling is relatively ineffective on certain species will usually be an insufficient reason for taking the trouble to poison them in the course of extensive stand improvement. Locally, where red and black gums are abundant and very undesirable, and where all must certainly be killed within at least 2 or 3 years, either felling or poisoning would be a better method than merely girdling.

5. - TO HASTEN THE DECAY AND FALL OF DEADENED TREES AND THUS MORE RAPIDLY DECREASE THE FIRE HAZARD OFFERED BY RESISTANT SNAGS. The available information on this point from the Ouachita study is that hardwoods poisoned with calcium chlorate fall somewhat more rapidly than merely girdled trees, but that hardwoods poisoned with sodium arsenite fall somewhat more slowly than merely girdled trees. In either case, the differences are small and probably of little or no practical significance. Thus the common belief that trees treated with any poisonous substance disintegrate and fall more rapidly than merely girdled trees is not borne out by the Ouachita study, and poisoning cannot be considered to have any advantage over girdling in this respect. At least one investigator, however, has found that arsenic-poisoned trees rot and fall more rapidly than merely girdled trees, so in view of the conflicting evidence no positive generalized statement can be made. The fact that there is conflicting evidence implies that there is little or no real or consistent difference between poisoning and simple girdling with respect to the rotting, disintegration, and fall of treated trees.

SUMMARY AND CONCLUSIONS

The preceding discussion may be summarized very briefly as follows:

1. - Felling by cutting close to the ground, and partial felling and bending over, are the best methods for killing or removing the crown competition of small hardwoods, up to 3 to 5 inches in diameter at breast height. Because of the sprouting that will usually occur, neither method is advisable if there are no pines or more valuable hardwoods to be released, or if these more valuable trees are less than about 5 feet high.

   An important exception to the last statement must often be made in the case of longleaf pine less than about 4 or 5 feet high and overtopped by relatively small scrub oaks. Omission of treatment in such stands may result in the death of a large proportion of the longleaf seedlings. In view of the relatively long interval between good longleaf seed years, and the usual delay that precedes any appreciable height growth of longleaf seedlings, the probable high mortality in untreated stands is usually con-

sidered a sufficient reason for stand improvement. However, the only method likely to be successful in permanently releasing small longleaf pines from scrub oaks involves at least one and usually several follow-up treatments-- cutting the oaks close to the ground and returning often enough to cut back the oak sprouts as often as they reach the height of the pines.

2. - Girdling is the best method for killing larger hardwoods. A "double-hack" or "chip" girdle, exposing about a 4-inch band of sapwood, offers the best combination of effectiveness and cheapness, with ordinary labor and for all species. If, however, the workmen are unusually experienced and conscientious, "single-hacking" or "frilling", with the edges of the cuts separated by twisting the ax, is likely to be satisfactory and is cheaper.

3. - Poisoning is usually unnecessarily expensive and unjustified by any outstanding or consistent advantages.

These statements are applicable to average stand-improvement operations in the South, and the word "best" merely implies the greatest excess of advantages over disadvantages for average conditions. For the citation of exceptions, qualifications, and unusual conditions that affect the choice of methods, the main body of this paper should be consulted.

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